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BROWN-ROT OF PRUNES AND CHERRIES IN THE PACIFIC NORTHWEST.

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INTRODUCTION.

For several years the growers of the lower Columbia and Willamette Valleys have had severe losses of their prunes and cherries. Among the causes have been a failure of the trees to set a full crop and a lack of keeping quality in the harvested fruit due to brown-rot. Occasional midsummer outbreaks of brown-rot have also occurred.

In the spring of 1914 Mr. M. B. Waite, Pathologist in Charge of Fruit-Disease Investigations, examined some diseased prune blossoms from Vancouver, Wash., and was in correspondence with the growers concerning the cause of the prune trouble. He has furnished the following manuscript note covering these investigations:

With a letter dated April 18, 1914, from Mr. Chapin A. Mills, Vancouver, Clarke County, Wash., addressed to the Department of Agriculture, specimens of spurs and twigs of the Italian prune (*Prunus domestica*), with dead and dying blossoms, were received, with an inquiry as to the cause and remedy for the bad condition of the blossoms, the dropping of the bloom and young fruit, and the widespread failure of the crop to "set" or hold its fruit. A few days later a similar set of specimens was received from the same district, and a number of inquiries, without specimens, reached us from Washington, Oregon, and California, including the Sacramento and Santa Clara Valleys, as to the cause of the failure of the prunes to set their fruit.

NOTE.—This bulletin is intended particularly for the benefit of prune and cherry growers of western Washington and Oregon, but is of interest to growers of these fruits in other sections of the United States. It is also of scientific interest to plant pathologists in general.

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A microscopic examination of the blighting blossoms showed them to be infected with the ordinary brown-rot fungus, which for the present may be designated by the name *Sclerotinia cinerea*. The specimens showed that the conidial or "Monilia" form of the fungus had attacked the bloom in various stages, killing some of the buds before they had opened, often penetrating the entire flower and extending down the pedicels. Some of the blossoms had set their fruit, and the young prune had started to develop before the flower was completely killed. In some cases the young fruits were penetrated; in others they were not yet occupied by the fungus, which had partly killed the flower and spread down the pedicel. The conidial form of the fungus was fruiting abundantly over most of the surface of the diseased organs.

An extended correspondence was carried on with the growers during the spring and summer of 1914, in which it was developed that the prunes in that section had been dropping quite badly for several years from causes unknown to the orchardists; that rather cool, rainy weather occurred during blossoming time in 1914—not severe, heavy rains, but continuous damp weather. The prunes "made a good setting, but immediately seemed to stop their growth, and the 'husk' gradually dried and adhered to the prune, finally all falling off." Naturally, the possibility of control of the fungous trouble by early spraying was suggested in the correspondence.

Notwithstanding this very definite evidence that the specimens of prune blossoms received were killed by the brown-rot fungus, it was suggested as not safe to at once conclude that the whole trouble of nonsetting of prunes was due to this fungus, since the same rainy weather which would favor the brown-rot fungus would also interfere with the pollination and fertilization of the fruit. Nutrition factors and general temperature conditions would also be concerned in the problem of prune dropping. It seemed hardly probable that the brown-rot fungus could be charged with all the difficulties, including those of the Sacramento and Santa Clara Valleys in California.

Subsequently, from specimens of partly ripe cherries received from Mr. A. W. Moody, of Vancouver, Wash., with a letter dated July 11, 1914, a serious trouble with the ripening cherries was also identified as caused by the brown-rot fungus.

The brown-rot fungus is well known to be widely distributed on the Pacific coast in the more humid sections near the ocean. It has been studied and figured by the pathologists of California and Oregon, but always on the ripening fruit. The writer saw it on ripe prunes at Vancouver, Wash., in September, 1907, in the district from which these specimens came. The blossom-blight phase of this disease appears not to have attracted attention as a disease of prunes and other stone fruits on the Pacific coast.

BLOSSOM INFECTION OF PRUNES.

Blossom infection of brown-rot on cherries in New York was reported by Arthur[1] as early as 1885, and a blossom blight of peaches in Delaware was described by Smith[2] a few years later.

In the summer of 1913 the junior writer obtained information in regard to a peculiar and severe early drop of prunes in Clarke County, Wash., the effects reported being very similar to those of the Monilia blossom blight of the peach as he had observed it in the East. The following summer he made a visit to the section mentioned to study the prune situation. The data collected showed that the prune orchards had again suffered from a severe blossom blight and that the

[1] Arthur, J. C. Rotting of cherries and plums. *In* N. Y. State Agr. Exp. Sta., 4th Ann. Rpt., 1885, p. 280–285. 1886.

[2] Smith, Erwin F. Peach rot and peach blight. *In* Jour. Mycol., vol. 5, no. 3, p. 123–134. 1889.
——— Peach blight. *In* Jour. Mycol. v. 7, no. 1, p. 36–38, 2 pl. 1891.

conditions were such as to indicate that the brown-rot organism was an important factor in the case.

In the spring of 1915 the prune orchards in the vicinity of Vancouver, Wash., were kept under close observation, and a record was made of orchard and weather conditions. March 28 and 30 were fair days, but with these exceptions it rained almost continuously from March 24 to April 8. The trees were in full bloom on March 28, and on April 5 the blossoms were falling. On the latter date there was no evidence of typical blossom blight as it usually occurs in eastern sections, but many of the calyx cups were turning brown on the under side where drops of water had hung, and the margins of the sepals were often similarly affected. On April 8 some of the young fruit was turning yellow and dropping, apparently from lack of fertilization of the blossoms. At this time the browning of the calyxes had become much more serious, involving in some cases more than three-fourths of the crop of the unsprayed trees. It was much more abundant on the lower than on the upper branches and seemed to be as common on the fertilized as on the unfertilized fruit. In some cases the browning spread down the pedicel, the fruit often turning back on its stem; in others it involved most of the calyx, the young fruit separating readily from it. (Pl. I, figs. 4, 5, and 6.) The latter condition was more common on the fertilized blossoms. When placed in a moist chamber, the affected fruit developed an abundant growth of Monilia, the conidial stage of *Sclerotinia cinerea* (Bon.) Wor.[1]

On April 12 a heavy drop was taking place, both of the unfertilized and the fertilized but infected fruit. At this time the fertilized fruit could be readily distinguished from the apparently unfertilized by its enlarged ovary, its lengthened pedicel, and its darker green color.

The brown-rot fungus produces two distinct types of spores—one, the Monilia or summer form, which gives the characteristic mouse-colored appearance to the rotting fruit; the other, the mature or perfect stage, in which the spores are borne on the upper surface of cup-shaped fruiting bodies, known as apothecia, that develop from the mummied prunes.

On April 2 apothecia were evident under the trees on the diseased prunes of previous seasons. By April 8 they had developed in large numbers, 30 to 40 clusters often being found on the ground under one tree. (Pl. I, fig. 3.) On the latter date many of the apothecia had shed their spores, and by April 12 they were disappearing. Most of the apothecia came from prunes near the surface of the soil, and while some had unusually long stalks none could be found coming from a greater depth than 3 or 4 inches.

[1] Matheny, W. A. A comparison of the American brown-rot fungus with *Sclerotinia fructigena* and *S. cinerea* of Europe. *In* Bot. Gaz., v. 56, no. 5, p. 418–432, 6 fig. 1913.

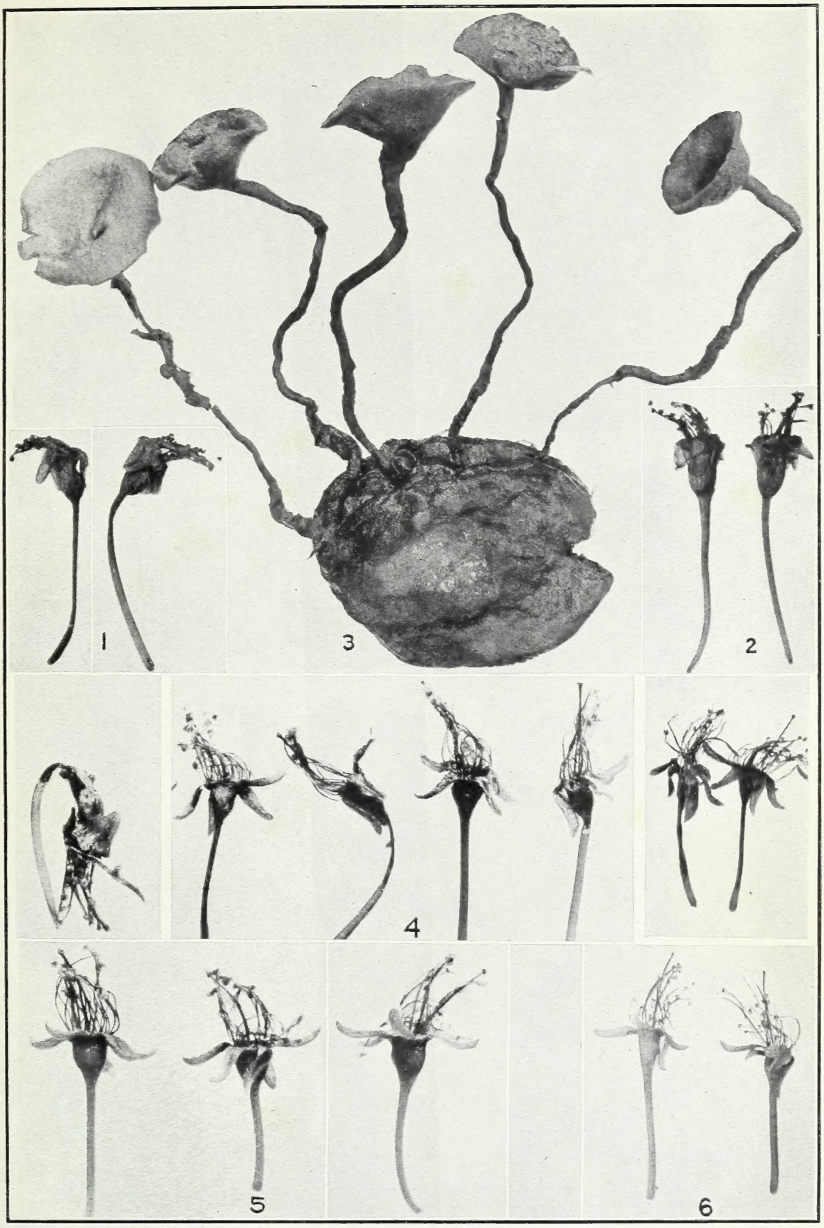
A comparison of the time of the development of the apothecia with the dates of infection on the prunes furnishes strong evidence that the apothecia were the source of infection. Further evidence of this may be found in the fact that Monilia could not be found in fruiting condition on cankered limbs, although a very careful search was made. The fact that the disease was much worse on the lower limbs than in the tops of the trees might be taken as further evidence that the infection was from below, but moisture conditions may have been of importance in producing this difference. It was also found that in orchards where early spring plowing and cultivation were practiced there was little or no calyx infection of brown-rot. While soil variations and the effects of culture upon the general vigor of the tree must not be lost sight of, there is little doubt that the deterrent effect of the cultivation upon the development of the apothecia was of direct value in the prevention of the disease.

The wind is probably the important agent in spreading the spores of the fungus. Insects may be concerned to some extent in this distribution, but are of greater importance on account of the punctures they produce on the fruit, these injuries furnishing an entrance point for the fungus. Among the insects, the fruit-tree leaf syneta (*Syneta albida* Leconte) is probably of importance, as it was present in great numbers during the early part of the season, feeding on both fruit and foliage and causing much damage.

SPRAYING EXPERIMENTS.

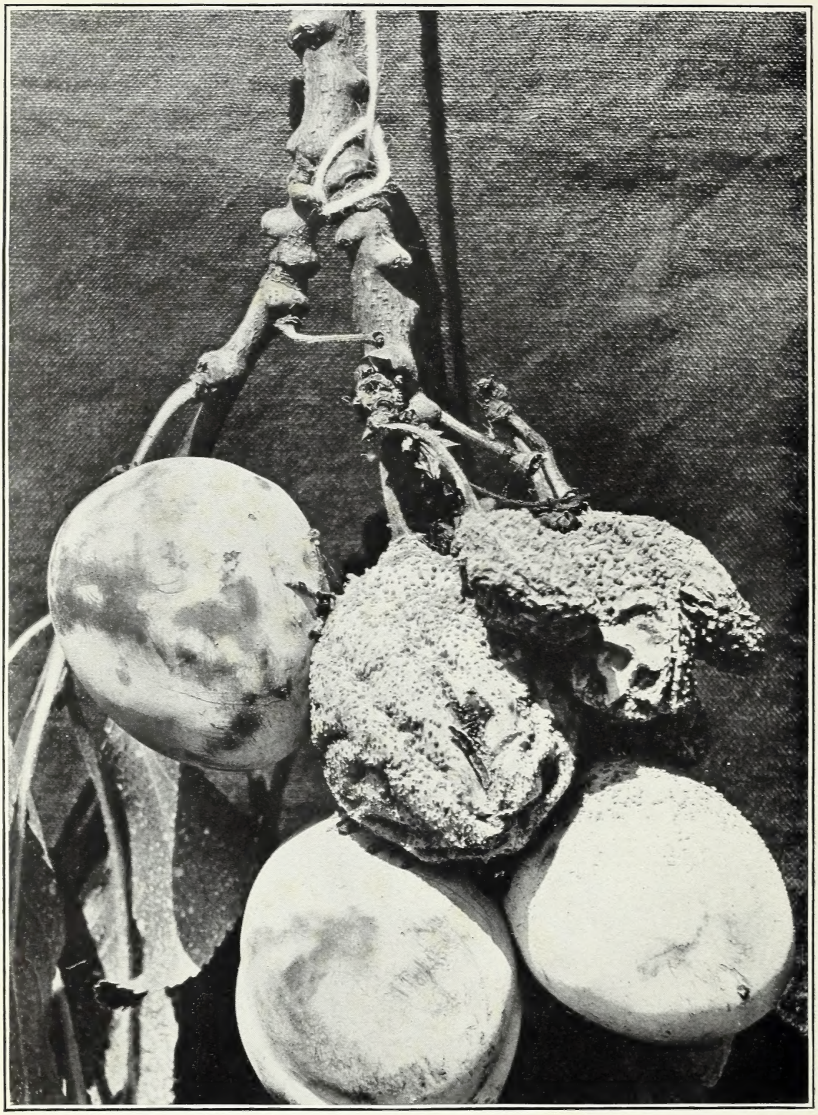
Further evidence of the importance of the blossom infection was obtained from the spraying experiments of the season of 1915. The work was carried on in the orchards of A. W. Moody, at Felida, Wash. The first spraying was made on March 17, when the buds were beginning to swell, a second on March 24, when the cluster buds were open and the blossoms showing white, and a third on April 8, when the petals were practically all off. The first application was made with 4–4–50 Bordeaux mixture; the later ones with 8–8–50 self-boiled lime-sulphur. No spreader or sticker was added in any of these applications. At the time of the third spraying but little evidence of the second could be found on the trees. The two weeks of almost constant rain had apparently washed most of it off. It was evident that something should have been added to the fungicides to increase their adhesive qualities. It was also evident from the time the infections appeared that better results would have been secured if the second and third applications had been nearer together.

The heavy infection described, which had taken place previous to the third spraying, made it plain that it was then too late to secure the best results. Notes taken May 10 to 15, however, showed that the spraying had saved a considerable percentage of the crop. At that



CHERRIES AND PRUNES AFFECTED WITH BROWN-ROT.

FIG. 1.—Black Republican cherries affected with brown-rot, collected at Salem, Oreg., April 13, 1915. FIG. 2.—Same as figure 1, but not affected with brown-rot. FIG. 3.—Italian prune mummy bearing five apothecia, collected at Felida, Wash., April 9, 1915. This prune was buried to a depth of about 2 inches and the apothecial cups were borne just above the surface of the soil. FIG. 4.—Italian prunes affected with brown-rot, collected at Felida, Wash., April 9, 1915. FIG. 5.—Same as figure 4, but not affected with brown-rot. FIG. 6.—Same as figure 5, but these are blossoms that were yellow and apparently unpollinated. Note the small size of the ovaries in comparison with those of figures 4 and 5. All the photographs reproduced above were taken from specimens that had been preserved in formalin.



ITALIAN PRUNES AFFECTED WITH BROWN-ROT.

Photographed when the fruit was beginning to color, August 11, 1915.

time the number of fruit spurs that had borne blossoms and the number of prunes still remaining were counted on representative branches from the various plats. The results obtained are shown in Table I.

TABLE I.—*Prune spraying experiments at Felida, Wash., in March and April, 1915.*

Plat.	Sprayings.	Prunes per 4,000 spurs.	Plat.	Sprayings.	Prunes per 4,000 spurs.
No. 2	First, second, and third	292	No. 9	First and third	143
No. 3	First and second	243	No. 10	None	69
No. 7	Second	369	No. 6	do	86

These results show that the sprayed trees had retained from two to five times as much of their fruit as the unsprayed ones. A comparison of the set of fruit on the different sprayed plats would indicate that the second spraying was the most important one, but that the third was also very valuable. A study of the final crop from the orchard, as given later, shows that the average yield on the nine plats that received an application of self-boiled lime-sulphur, either in the second or third spraying or both, was more than two and a half times as great as that from plats 6, 10, and 11, which received no early spraying.

If an adhesive had been added to the fungicide in the second application, there is little doubt that the results would have been much more striking, for, as already mentioned, much of this spray had been washed off by rains before the third application was made, thus leaving but poor protection during the most critical period of infection.

The above data show very conclusively that the blossom blight was an important factor in the poor set of fruit obtained in 1915. Observations on the calyx browning and on the fruit drop in several different sections of southwestern Washington and also in the orchards near Salem, Oreg., indicated that the conditions described for Vancouver were of general occurrence in the prune orchards of the lower Columbia and Willamette Valleys.

FRUIT ROT OF PRUNES.

The orchard observations were continued throughout the summer, and records were kept of weather conditions and the prevalence of disease. Frequent showers occurred during the last three weeks of May, but the weather during the latter part of the summer was comparatively dry, the rainfall being considerably below the average for the season.

The occurrence of brown-rot was noted on some of the plats in the latter part of May, but there was no serious outbreak at any time during the summer.

The spraying experiments were continued throughout the season. In addition to the dormant spray of March 17, the bud spray of March 24, and the calyx spray of April 8, a fourth application was made May 1 to 4, a fifth May 29, a sixth June 14, and a seventh August 6, about a month before harvest.

The following spray materials were used:

F1. Bordeaux mixture, 4–4–50.
F2. Same as F1, but with 2 pounds of resin-fishoil soap added.
F3. Self-boiled lime-sulphur, 8–8–50.
F4. Same as F3, but with 2 pounds of resin-fishoil soap added.
F5. Same as F3, but with three-fourths pound of dry powdered arsenate of lead added.
F6. Commercial lime-sulphur, 1½ to 50.
F7. Commercial lime-sulphur, 1 to 50.
F8. Same as F6, but with 2 gallons of flour paste added.

The flour paste was made by boiling 1 pound of flour in 1 gallon of water about half an hour, until a thick paste was formed. The resin-fishoil soap was purchased on the market in the East. It can not be readily obtained on the Pacific slope, but may be made up as follows:

Resin	5 pounds.
Potash lye, such as is sold for washing purposes	1 pound.
Fish oil	1 pint.
Water	5 gallons.

The resin is dissolved in the oil by heating in a large kettle. After this has partially cooled, the potash is added, the mixture being slowly stirred and carefully watched to prevent its boiling over. A part of the water is now added and the boiling continued till the mixture will dissolve in cold water. This will require about one hour. The remainder of the water is then slowly added and the mixture thoroughly stirred. The resin-fishoil soap was found very valuable in making the spray adhere to the fruit. It can not be used with commercial lime-sulphur.

It was found that the fruit was covered better when a driving type of nozzle was used. None of the sprays used caused any injury. The second orchard adjoined the first. The trees were younger and had borne but a very light crop the previous year. Apothecia were of rare occurrence in this orchard in the spring.

The prunes were harvested September 7 to 10. A count was made of the entire prune crop of the five trees of each plat. A crate of sound fruit was packed from each of the more important plats, the packed samples being stored in a noncooled orchard warehouse until September 14 and then shipped by express to Wenatchee, Wash. The figures in the last column of Table II show the percentage of brown-rot that had developed 12 days after harvesting.

TABLE II.—*Spraying for brown-rot of prunes at Felida, Wash., during the season of 1915.*

Plat.	Sprayings.[1]							Yield (number of prunes).	Brown-rot (per cent).	
	1st.	2d.	3d.	4th.	5th.	6th.	7th.		At harvest.	After 12 days' storage.
First orchard:										
No. 1	F1	F3	.....	F4	.....	F4	F4	723	0.27	.....
No. 2	F1	F3	F3	F4	.....	F4	F4	1,410	.78	2
No. 3	F1	F3	.....	.....	.....	F4	F4	1,636	.48	6
No. 4	F1	F3	.....	F4	.....	.....	F4	1,761	1.08	15
No. 5	F1	F3	.....	F4	.....	F4	.....	3,582	.19	1
No. 6	.....	.....	.....	.....	.....	.....	.....	1,150	3.39	41
No. 7	.....	F3	.....	F4	.....	F4	F4	1,985	.15	3
No. 8	.....	F3	.....	F3	.....	F3	F3	2,911	.28	8
No. 9	F1	.....	F3	F3	.....	F3	F3	1,608	.12	3
No. 10	.....	.....	.....	F4	.....	F4	F4	720	.28	.....
No. 11	.....	.....	.....	.....	.....	F4	F4	493	2.43	.....
No. 12	F1	.....	F5	F5	.....	F5	F5	2,582	.27	2
No. 13	F1	.....	F1	F2	.....	F2	F2	[2] 684	.....	.....
No. 14	F1	.....	F1	F1	.....	F1	F1	[2] 519	1.15	.....
No. 15	F1	F6	.....	F6	.....	F6	F6	1,804	.28	12
No. 16	F1	.....	F7	F7	.....	F7	F7	2,392	1.05	9
Second orchard:										
No. 17	F1	.....	.....	.....	F2	F2	F2	4,391	4.16	51
No. 18	F1	.....	.....	.....	F8	F8	F8	5,633	4.67	25
No. 19	F1	.....	.....	.....	F4	F4	F4	5,295	3.29	37
No. 20	F1	.....	.....	F1	.....	.....	.....	4,673	5.35	95

[1] The symbols, F1, F2, etc., refer to the spray formula used, as explained on p. 6.
[2] Fruit shriveled from an unknown cause.

The favorable effect of the early applications on the yield has already been discussed. The amount of brown-rot at harvest time was not large on any of the plats, but in the first orchard there was more than nine times as much on plat 6, which was unsprayed, as the average amount on the nine plats which received both early and late applications of self-boiled lime-sulphur, the former having 3.39 per cent of brown-rot, the latter 0.36 per cent. In the second orchard, plat 20, which received no late spray, had nearly twice as much brown-rot as plat 19, which received late applications with the above fungicide. The contrasts on the stored fruit were still more striking, because of the larger amounts of the disease. The prunes from the unsprayed plat of the first orchard had developed 41 per cent of brown-rot, while the average from the sprayed trees mentioned above was 5 per cent. In the case of the second orchard, the unsprayed fruit had 95 per cent of brown-rot, while that which received a late spraying with self-boiled lime-sulphur had 37 per cent and that sprayed with commercial lime-sulphur 25 per cent.

In some of the neighboring orchards where no sprayings were made, more than three-fourths of the crop was affected with brown-rot at harvest time (Pl. II). In such cases the fruit that was harvested was handled with great difficulty, as it would scarcely be in a usable condition if allowed to stand over night at the drier.

It is evident that spraying is not only of great value in securing a yield, but also in the harvesting operations, and that if the fresh prunes are to be marketed it is absolutely indispensable.

In the summer of 1915 the rainfall at Portland, Oreg., 15 miles distant, was below the average and very decidedly so in March, April, and September, the months in which the most critical periods of infection apparently occur. It is the number of damp days rather than the inches of rainfall that actually determines the opportunity for infection, but in this respect also the season of 1915 was not unusually favorable to the disease. It seems probable, therefore, that spraying and other remedial measures would be of even greater importance in other years than the results in 1915 show for that season.

SUMMARY AND CONCLUSION FOR PRUNES.

The above observations and results indicate that in such seasons as that of 1915 the brown-rot problem is one of great importance to the prune industry in the more humid sections of the Northwest. It has been shown that the apothecia which develop from the fallen prunes are the probable source of the blossom infection. Fall plowing and early spring cultivation ahead of the blossoming period have apparently helped to prevent the disease by interfering with the development of the apothecia.

The early applications of spray were washed off, showing the importance of the addition of a sticker, but even with rather unsatisfactory conditions spraying has given fairly good results. The plats given both early and late sprayings with self-boiled lime-sulphur set from two to five times as much fruit as the unsprayed ones, gave two and a half times as large a yield, and had one-ninth as much brown-rot on the harvested and one-eighth as much on the stored prunes. Self-boiled lime-sulphur and Bordeaux mixture have both given good results, but the former has seemed somewhat more satisfactory. Bailey has also reported good results from the use of these fungicides on prunes.[1]

The sticking and spreading qualities are greatly improved by the addition of 2 pounds of resin-fishoil soap to each 50 gallons of the mixture.

Several years' results will be necessary as a basis for any final recommendations, but in so far as the season of 1915 was typical the following schedule of spraying may be suggested:

The first application just before the blossoms open.
A second just after the petals have fallen.
A third three to four weeks later, just after the husks have fallen.
A fourth about four weeks before harvesting.

[1] Bailey, F. D. Experimental spraying of prunes for control of brown-rot. *In* Oreg. Agr. Exp. Sta., 2d Bien. Crop Pest and Hort. Rpt. 1913–14, p. 241–244. 1915.

IMMATURE ROYAL ANN CHERRIES AFFECTED WITH BROWN-ROT.

Photographed May 25, 1915.

The first and fourth applications have been especially important the past season.

BLOSSOM INFECTION OF CHERRIES.

Observations made near Vancouver, Wash., on April 8 and in the vicinity of Salem, Oreg., on April 13 showed that there had been a blossom infection of cherries similar to that already described on prunes (Pl. I, figs. 1 and 2). On the latter date Monilia was fruiting luxuriantly on the blighted cherries. It appeared that most of the infection had taken place after the petals had fallen and before the fruit had had a chance to push through the husk. Black Republican cherries seemed especially badly infected. Estimates made on April 13 indicated that on this variety fully 90 per cent of the blossoms were infected with Monilia, and in many orchards of other varieties at least 75 per cent were similarly infected. A grower near Felida, Wash., sprayed some of his cherry trees while they were in full bloom, using lime-sulphur solution diluted 1 to 30. He delayed the spraying of the others until the calyx browning had begun to appear and then applied the same spray he had used earlier. Counts made on April 8 of representative branches from each lot of trees showed 9 per cent of infected fruit in the former case and over 40 per cent in the latter. Spraying trees in full bloom is not to be recommended, but the results show the value of early spraying.

BROWN-ROT OF CHERRIES.

Spraying experiments for the control of brown-rot on the fruit were carried on in the orchard of L. T. Reynolds, of Salem, Oreg. The work was begun late in the season. The first application was made on May 7 and 8, when the fruit had begun to color, and a second on June 1, when the fruit was approaching maturity. The latter application was delayed for nearly a week on account of rain.

Plat 1 received Bordeaux mixture, 2–4–50, plus 2 pounds of resin-fishoil soap; plat 2, commercial lime-sulphur, 1 to 50; plat 3, self-boiled lime-sulphur, 8–8–50, plus 2 pounds of resin-fishoil soap; and plat 4 was unsprayed.

No injury resulted from the use of any of the fungicides. The Royal Ann cherries were picked on June 17 and the Black Republicans on June 24. A regular 10-pound box of sound cherries was packed from each plat and placed in cold storage at 40° F. until June 27, and the fruit was then shipped by express to Wenatchee, Wash. Notes on the Royal Anns were taken on July 2 and on the Black Republicans on July 6. The former were thus in cold storage at 40° F. for 10 days and at air temperature for 6 days, the latter in cold storage for 3 days and at air temperature for 10 days. Table III gives the results obtained.

TABLE III.—*Spraying cherries for the control of brown-rot at Salem, Oreg., during the season of 1915.*

Plat.	Treatment, if any.	Brown-rot (per cent).			
		Royal Ann.		Black Republican.	
		At picking.	After storage.	At picking.	After storage.
No. 1	Bordeaux mixture	0.17	11	0.03	7
No. 2	Lime-sulphur			.05	8
No. 3	Self-boiled lime-sulphur	.25	14	.07	2
No. 4	Unsprayed	.67	55	.03	18

There was not enough brown-rot evident on any of the plats at picking time to make the contrasts of any great interest. (Pl. III.) After the severe storage tests the effects of spraying were more evident, the fruit from the self-boiled lime-sulphur plat having only one-fourth as much brown-rot as that from the unsprayed plat in the case of the Royal Anns and one-ninth as much in the case of the Black Republicans. With the Royal Anns better results were secured with Bordeaux mixture than with the self-boiled lime-sulphur. The sprayed fruit held up much better at the local canneries than the unsprayed fruit.

SUMMARY AND CONCLUSION FOR CHERRIES.

While the work on cherries has not been carried out as fully as was desired, it seems evident that the Monilia blossom blight was the cause of serious losses in the Willamette Valley in the season of 1915 and the brown-rot of the fruit the cause of considerable loss at the canneries and heavy losses in the shipping of fresh fruit. No early sprayings were made, and therefore no results were obtained on the effect of spraying upon the blossom infection. The brown-rot at the canneries and in storage has been greatly reduced by late applications of Bordeaux mixture and self-boiled lime-sulphur. It seems probable that a treatment for cherries similar to that outlined for prunes would give satisfactory control of both the blossom infection and the later brown-rot attacks on the fruit.

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